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ASSESSMENT OF THE NUTRITIONAL QUALITIES OF A LOCALLY-PRODUCED WEANING BLEND OF SORGHUM OGI FLOUR FORTIFIED WITH BAMBARA GROUNDNUT FLOUR

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ABSTRACT

This study investigated the nutritional quality of a locally-produced weaning blend of sorghum ogi flour fortified with Bambara groundnut (BGN) flours and the role of lactic acid bacteria (LAB) as starter in the reduction of anti-nutrients in the pre-treated BGN flours. LAB were isolated from fermented sorghum ogi, processed into flour. BGN were processed into flours using three pre-treatment methods and used to fortify the sorghum ogi flour in ratio 60:40. Proximate composition and the breakdown of anti-nutritional factors by LAB were monitored in the pre-treated BGN flours using standard procedures. Sensory, organoleptic attributes and shelf-life of the weaning blends were determined. Sorghum ogi flour fortified with roasted BGN flour had improved nutritional value; protein, ether extract, ascorbic acid, riboflavin, β-carotene, calcium, and phosphate (mg/100g) 20.16, 6.43, 21.00, 0.13, 90.00, 145.00 and 280.00 respectively compared to boiled and soaked BGN flours. There was a reduction in the anti-nutritional factors of the pre-treated BGN flours when fermented with selected starter. Tannin, phytate, protease and trypsin inhibitors reduced significantly ($p< 0.05$) from 0.074 - 0.048; 5.901- 5.001; 0.052 - 0.043 and 0.137 -0.110 respectively. The shelf-life monitoring and organoleptic assessment showed that sorghum Ogi flour fortified with roasted BGN flour had a prolonged shelf life and was generally accepted when compared to other weaning blends. The study concluded that the weaning blend had improved nutritional composition required for a growing infant. LAB could be used as starters to reduce anti-nutritional factors and extend the shelf-life of pre-treated Bambara groundnut-sorghum ogi blends.

Contribution/Originality: The paper's primary contribution is finding that adequate weaning food can be prepared locally with minimal funds. The blend is able to meet the daily nutritional requirement of a growing infant. It also advances the contribution of women especially in low economic groups in reducing malnutrition and infant mortality rate.

1. INTRODUCTION

Malnutrition is one of the greatest problems affecting millions of people, particularly the children, in developing countries. This is due to lack of adequate intake of quantity and quality protein in their meals (Okorie *et*

al., 2015). Some of the staple foods in many developing countries lack important nutrients required by the infants and young children to satisfy their nutritional requirements.

Sorghum is a major crop of the semi-arid tropics of Africa and Asia, and is an important component in traditional farming systems and in diets of millions of people. The crop belongs to the elite handful of plants that collectively provide more than 85 % of all human energy. Traditional cereal foods such as sorghum (*Sorghum bicolor* L.) and maize (*Zea mays*) play an important role in the diet of the people of Africa (Mbata *et al*., 2009). One of such food product is *ogi*; fermented cereal using simple processing methods.

In Nigeria, *Ogi* prepared from sorghum or maize or millet grains are washed and steeped for 24 to 72 hours during which they undergo lactic acid fermentation. They are then drained, wet-milled and finally sieved to yield fine smooth slurry with about 8% solid and high water content. The major microorganisms associated with the fermentation of *ogi* are lactic acid bacteria and yeasts (Aworh, 2008). Lactic acid bacteria have been used in fermented foods due to their beneficial influence on nutritional, organoleptic, shelf-life characteristics and also used in food preservation where LABs can acidify the food resulting in inhibition of spoilage and pathogenic bacteria (Nishant *et al*., 2011). *Ogi*, produced from natural fermentation of cereals is an important food for weaning infants in many parts of West Africa (Aminigo and Akingbala, 2003). However, it is generally high in carbohydrate content and low in protein content especially amino acids such as lysine, methionine, threonine and tryptophan. This makes their nutrient composition insufficient enough to meet the nutritional requirements of the infants (Wakil and Kazeem, 2012).

Sorghum-*ogi* (*ogi-baba*) has been observed as one with low protein composition for infants (Ajanaku *et al*., 2012). Most of the nutrient contents such as proteins and minerals are lost during the processing (Zakari *et al*., 2010). This has led to many studies on the fortification of the gruel to enhance its nutritive value. One of the strategies to enhance the nutritional requirements of cereal meal is by supplementation with legumes such as Bambara groundnut, Soy-Beans, Lima –beans etc. Mugendi *et al*. (2010). Many brands of low - cost proprietary weaning foods have been developed from locally available high calorie cereals and legumes in tropical Africa (Sanni *et al*., 2001). This has been suggested by the Integrated Child Development Scheme (ICDS) and Food and Agriculture Organization (FAO) to combat malnutrition among mothers and children of low socio-economic groups. Bambara groundnut (*Vigna subterranean L*) belongs to the family of Fabaceae. It is an annual herbaceous, intermediate plant with creeping stems. The nuts are known as jugo beans (South Africa), *ntoyo ci-Bemba* (Republic of Zambia), *Gurjiya* or *Kwaruru* (Hausa, Nigeria), *Okpa* (Ibo, Nigeria), *Epa-Roro* (Yoruba, Nigeria) and *Nyimo* beans (Zimbabwe) (Bamshaiye *et al*., 2011). The colour of the seeds vary from white, cream, red, black and in some cases mottled with colours such as brown, red or black. The crop is known for its tolerance to drought, relative resistance to pests, diseases and the ability to produce good yields in poor soils too poor to support the growth of other legumes (Brough and Azam- Ali, 2003).

Earlier studies have documented the need for fortification of traditional fermented cereals porridge with legume such as Bambara groundnut, Lima beans, and Soy beans (Mbata *et al*., 2007). Inadequate intake of protein meals predisposes an individual to malnutrition. *Ogi* from cereals, commonly fed to growing infants is inadequate in essential amino acids. This deficiency can be ameliorated through supplementation with legumes such as Bambara groundnut. However, the efficacy of Bambara groundnut as supplements of *Ogi* from cereals has not been adequately examined.

Therefore, the study aimed at investigating the nutritional qualities of a locally produced weaning blend of fermented sorghum ogi fortified with pre-treated Bambara groundnut flour.

2. MATERIALS AND METHODS

2.1. Collection of Samples

Sorghum (*Sorghum bicolor* L), and cream coat Bambara groundnut (*Vigna subterranea* L.) were purchased from Atakunmosa market 7°37'18.8"N 4°44'21.0"E, Ilesa, Osun state, Nigeria. They were collected in clean polyethene bags and were transported to the laboratory for production and microbiological analysis.

2.2. Preparation of Samples

All the samples used for this analysis were first surface-sterilized by cleaning in 1% sodium chloride solution for 5 mins and was rinsed several times with distilled water before further processing.

2.3. Preparation of Traditional Sorghum Ogi

Two hundred gramme (200g) of sorghum grains were cleaned and steeped in clean plastic bucket containing 300 mL of distilled water for 96 h at room temperature (28 ± 2°C). The steeped grains were washed thoroughly with distilled water, wet-milled by using a disc attrition mill (Hunt No. 2A premier mill, Hunt and Co, UK), and wet-sieved by using a cleaned Muslin cloth. It was allowed to set and ferment for another 24 h. The sorghum *ogi* slurry was obtained by decanting the steeped corn water and was dewatered by applying hydraulic pressure when packed into clean Muslin cloth. It was then dried at a temperature of 55 ± 5°C for 48 h, dried milled into *ogi* powder by using a clean electric grinder (VTCL mixer grinder), sieved through a fine mesh with 0.5mm pore size and was stored in an air-tighted plastic bucket at room temperature. This was done according to method of Awoyade *et al.* (2016).

2.4. Preparation and Pre-Treatment of the Bambara Groundnut

Two hundred grammes (200g) of the Bambara groundnut seed were cleaned by sorting out the good ones and were pretreated by applying three different pre-treatment methods which include boiling, roasting and soaking. This was carried out according to the method of Mbata *et al.* (2009) as modified by Adeyemo and Onilude (2013).

BOILED BGN: Two hundred grammes (200g) Bambara groundnut was boiled in 300 mL of distilled water at temperature of 100°C for 20 mins. It was dehulled and washed several times with distilled water to remove the seed coat. It was then drained, dried in an electric oven at 50°C (Hearson Willow model) for 48 h, dried-milled into powder by using a clean electric grinder (VTCL mixer grinder), sieved through a fine mesh with 0.5mm pore size and was stored in an air-tighted plastic bucket at room temperature. SOAKED BGN: Two hundred grammes (200g) Bambara groundnut was soaked for 24 h in 300 mL of distilled water and dehulled. It was then drained, dried in an electric oven (Hearson Willow model) at 50°C for 48 h, dried-milled into powder by using a clean electric grinder (VTCL mixer grinder), sieved through a fine mesh with 0.5mm pore size and was stored in a air-tighted plastic bucket at room temperature. ROASTED BGN: Two hundred grammes (200g) Bambara groundnut was roasted in an oven (Hearson Willow model) at 100°C, dehulled to remove the seed coat and milled into powder by using a clean electric grinder (VTCL mixer grinder), sieved through a fine mesh with 0.5mm pore size and was stored in an air-tighted plastic bucket at room temperature.

2.5. Preparation of the Cereal Blend

This was carried out according to the method of Mbata *et al.* (2009) as modified by Adeyemo (2012). The sorghum *ogi* flours were mixed with various pre-treated BGN in 60:40 (w/w), and were stored in an air tighted plastic bucket at room temperature. The proximate analysis and antinutritional factors of the samples were determined.

2.6. Proximate Analysis

Moisture content, Ash content, Crude Fat, Protein, Crude Fibre and Carbohydrate were determined by the method of Association of Analytical Chemist (AOAC) (1990).

2.7. Determination of Vitamins and Minerals in the Weaning Blends

Ascorbic Acid, B Vitamins (Riboflavin and Thiamine), Niacin, β-carotene and the determination of Iron, Calcium, Zinc, Magnesium and Phosphate in the weaning blends were determined by the method of American Association of Cereal Chemist (2008).

2.8. Spontaneous Fermentation of the Pretreated Bambara Groundnut Flours

The pretreated BGN flours were fermented with the selected starter culture and were used in the breakdown of antinutrient in BGN flours. Breakdown of tannin, phytate, trypsin inhibitor and protease inhibitor in the pretreated BGN flours with selected starter culture were determined using the method of AOAC (1990).

2.9. Packaging of the Weaning Blends

The method of Oguntona and Akinyele (2002) as modified by Adeyemo (2012) was used in the packaging of the weaning blends. The weaning blends were stored in an air tight plastic container. It was then sealed in nylon, labelled accordingly and stored at room temperature.

2.10. Statistical Analysis

Data were obtained in replicates of two or three and were analyzed by using ANOVA, Mean, and Standard deviation. Significant differences between Means were determined at 95% confident limit ($p< 0.05$) and were compared using Duncan Multiple Range Test with the aid of SAS program (Snedecore *et al*., 2015).

3. RESULTS

The proximate composition of sorghum *ogi* flour, boiled, roasted, soaked, raw BGN and the weaning blends are presented in Table 1 and Table 2 respectively. Sorghum *ogi* had protein content, carbohydrate, ether extract, ascorbic acid, β-carotene, calcium and phosphate in (mg/100g) of 9.13, 82.26, 1.13, 12.30, 68.33, 153.33, and 210.00 respectively. Roasted BGN flour had improved nutritional value in protein, ether extract, ascorbic acid, riboflavin, β-carotene, calcium, and phosphate (mg/100g) of 20.16, 6.43, 21.00, 0.13, 90.00, 145.00 and 280.00 compared to boiled and soaked BGN flours. Sorghum *ogi* flour fortified with roasted Bambara groundnut shows a significant increase in the nutritional composition compared to other blends. There was an increase in protein, ether extract, ascorbic acid, thiamin, riboflavin, niacin, calcium, magnesium, iron and phosphorus (mg/100g) with a value of 12.23, 3.76, 19.66, 0.36, 0.31, 145.00, 65.66, 11.03, and 255.00 respectively.

The result of the breakdown of the anti-nutritional factors (Tannin, Phytate, Trypsin inhibitors and Protease inhibitors) were shown in Table 3, Table 4, Table 5, and Table 6 respectively. Anti-nutrients (tannin, phytate, protease and trypsin inhibitors) were significantly reduced ($p< 0.05$) from 0.074 - 0.048; 5.901- 5.001; 0.052 - 0.043 and 0.137 -0.110, respectively in the pre-treated Bambara groundnut flours when fermented with *Lactobacillus plantarum* and *Lactobacillus delbrueckii*.

Table-1. Result of the proximate composition sorghum *Ogi* flour, boiled, roasted, soaked and raw BGN.

Parameters (%)	B	X	Y	Z	K
Moisture content	9.13±0.15^{ab}	8.73±0.05^{cd}	8.26±0.15^{e}	8.56±0.15^{d}	8.83±0.05^{cd}
Protein	3.76±0.15^{h}	19.16±0.13^{c}	20.16±0.15^{a}	19.16±0.15^{c}	19.76±0.15^{b}
Ash	1.63±0.15^{f}	2.70±0.10^{bc}	3.20±0.10^{a}	2.63±0.15^{c}	2.90±0.10^{b}
Crude fibre	2.06±0.15^{fg}	2.70±0.10^{cd}	3.00±0.10^{ab}	2.90±0.10^{cb}	3.13±0.15^{a}
Carbohydrates	82.26±0.25^{b}	61.13±0.15^{g}	58.93±0.20^{i}	60.86±0.058^{g}	59.66±0.15
Ether extract (Fat)	1.13±0.15^{g}	5.56±0.15^{c}	6.43±0.15^{a}	5.86±0.15^{b}	5.70±0.10^{bc}
Ascorbic acid	12.30±0.10^{f}	17.66±1.52^{dc}	21.00±1.00^{b}	15.33±1.52^{de}	30.00±5.00^{a}
Thiamin	0.35±0.01^{cab}	0.32±0.01^{cd}	0.36±0.01^{ab}	0.37±0.01^{a}	0.37±0.01^{a}
Riboflavin	0.25±0.02^{a}	0.13±0.01^{ed}	0.13±0.01^{ed}	0.11±0.01^{e}	0.14±0.01^{cd}
Niacin	2.86±0.15^{a}	1.83±0.15^{de}	2.06±0.15^{dc}	1.66±0.15^{e}	2.13±0.15^{bc}
β-carotene (µg/100g)	68.33±7.63^{cd}	81.66±2.88^{ab}	90.00±5.00^{a}	73.33±2.88^{cb}	90.00±5.00^{a}
Ca^{2+}	153.33±2.88^{ab}	135.00±5.00^{ed}	145.00±5.00^{cb}	125.00±5.00^{z}	160.00±5.00^{a}
Fe^{2+}	9.60±0.20^{e}	12.16±0.15^{b}	12.46±0.15^{b}	12.16±0.15^{b}	12.76±0.15^{a}
Mg^{2+}	60.00±5.00^{de}	66.66±2.88^{cde}	70.00±5.00^{cab}	73.33±2.88^{ab}	75.00±5.00^{a}
PO_4^{3-}	210.00±5.00^{b}	261.66±2.88^{c}	280.00±5.00^{b}	276.66±2.88^{b}	290.00±5.00^{a}
Zn^{2+}	0.60±0.10^{a}	0.56±0.11^{a}	0.60±0.10^{a}	0.63±0.05^{a}	0.667±0.058^{a}

*Values are the Means ± Standard Deviation where n = 3. †Values with different superscript letter within each row are significantly different ($p< 0.05$) using Duncan's Multiple Range Test Sample B: Sorghum *ogi* flour.
Sample X: Boiled BGN flour.
Sample Y: Roasted BGN flour.
Sample Z: Soaked BGN flour.
Sample K: Raw BGN seed.

Table-2. Results of the proximate composition of the sorghum *Ogi* flour fortified with the pre-treated BGN flour.

Parameters (%)	BX	BY	BZ
Moisture content	8.86±0.15^{cb}	8.90±0.10^{cd}	8.80±0.26^{cd}
Protein	10.76±0.15^{g}	12.23±0.15^{d}	11.76±0.15^{e}
Ash	2.13±0.15^{e}	2.40±0.10^{e}	2.33±0.15^{de}
Crude fibre	2.40±0.10^{e}	2.70±0.10^{cd}	2.53±0.15^{ed}
Carbohydrates	72.46±0.45^{d}	70.40±0.20^{f}	71.16±0.70^{e}
Ether extract (Fat)	3.36±0.15^{e}	3.76±0.15^{d}	3.50±0.20^{e}
Ascorbic acid	15.36±0.15^{de}	19.66±0.57^{bc}	12.66±1.52^{fe}
Thiamin	0.33±0.01^{cb}	0.36±0.06^{cab}	0.35±0.01^{ab}
Riboflavin	0.17±0.01^{c}	0.21±0.01^{b}	0.13±0.01^{ab}
Niacin	1.86±0.15^{b}	2.33±0.15^{de}	2.16±0.15^{bc}
β-carotene (µg/100g)	68.33±2.88^{cd}	76.66±2.88^{cb}	70.00±5.00^{cd}
Ca^{2+}	140.0±5.00^{cd}	145.00±5.00^{cb}	141.66±7.63^{c}
Fe^{2+}	10.70±0.26^{d}	11.03±0.15^{c}	10.633±0.15^{d}
Mg^{2+}	62.66±2.51^{cd}	65.66±2.88^{cde}	6.00±5.00^{cd}
PO_4^{3-}	240.00±5.00^{d}	255.00±7.63^{d}	241.00±5.00^{c}
Zn^{2+}	0.56±0.058^{ab}	0.56±0.05^{ab}	0.60±0.10^{a}

*Values are the Means ± Standard Deviation where n = 3. †Values with different superscript letter within each row are significantly different ($p< 0.05$) using Duncan's Multiple Range Test.
Sample BX: Blend of Sorghum ogi flour and Boiled BGN flour (60:40 w/w).
Sample BY: Blend of Sorghum ogi flour and Roasted BGN flour (60:40 w/w).
Sample BZ: Blend of Sorghum ogi flour and Soaked BGN flour (60:40 w/w).

Table-3. Breakdown of the tannin in the pretreated BGN flours with single starter culture (*Lactobacillus plantarum*) and mixed starter culture (*Lactobacillus plantarum and Lactobacillus delbrueckii*).

Sample code	Breakdown of Tanin by selected starter culture			
	Day 1	Day 3	Day 5	Day 7
Sample X fermented with A8 and B1	*0.062±0.001^{a}†	0.057±0.001^{b}	0.051±0.001^{c}	0.048±0.001^{d}
Sample X fermented with A8	0.064±0.001^{a}	0.059±0.001^{b}	0.055±0.001^{c}	0.052±0.001^{d}
Sample Y fermented with A8 and B1	0.082±0.001^{a}	0.079±0.001^{b}	0.075±0.001^{c}	0.069±0.001^{d}
Sample Y fermented with A8	0.083±0.001^{a}	0.081±0.001^{b}	0.078±0.001^{c}	0.074±0.001^{d}
Sample Z fermented with A8 and B1	0.062±0.001^{a}	0.059±0.001^{b}	0.054±0.001^{c}	0.050±0.001^{d}
Sample Z fermented with A8	0.061±0.001^{a}	0.056±0.001^{b}	0.053±0.001^{c}	0.049±0.001^{d}
Sample K fermented with A8 and B1	0.250±0.001^{a}	0.239±0.001^{b}	0.230±0.001^{c}	0.225±0.001^{d}
Sample K fermented with A8	0.259±0.001^{a}	0.242±0.001^{b}	0.232±0.001^{c}	0.228±0.001^{d}

*Values are the Means ± standard deviation where n = 3. †Values with different superscript within each row are significantly different ($p< 0.05$) using Duncan's Multiple Range test.
Sample X: Boiled BGN flour Sample Y: Roasted BGN flour.
Sample Z: Soaked BGN flour A8: *Lactobacillus plantarum.*
B1: *Lactobacillus delbrueckii.*

Table-4. Breakdown of the phytate in the pretreated BGN flours with single starter culture (*Lactobacillus plantarum*) and mixed starter culture (*Lactobacillus plantarum and Lactobacillus delbrueckii*).

Sample code	Breakdown of Phytate by selected starter culture			
	Day 1	Day 3	Day 5	Day 7
Sample X fermented with A8 and B1	*8.600±0.010^{a}†	7.400±0.001^{b}	6.510±0.001^{c}	5.001±0.001^{d}
Sample X fermented with A8	8.610±0.001^{a}	7.628±0.001^{b}	6.833±0.001^{c}	5.570±0.001^{d}
Sample Y fermented with A8 and B1	8.332±0.001^{a}	6.333±0.001^{b}	5.497±0.006^{c}	5.180±0.001^{d}
Sample Y fermented with A8	8.766±0.001^{a}	7.967±0.058^{b}	6.897±0.007^{c}	5.901±0.001^{d}
Sample Z fermented with A8 and B1	7.990±0.001^{a}	6.995±0.001^{b}	5.371±0.001^{c}	5.290±0.001^{d}
Sample Z fermented with A8	8.100±0.001^{a}	7.200±0.001^{b}	6.100±0.001^{c}	5.310±0.001^{d}
Sample K fermented with A8 and B1	9.200±0.001^{a}	8.800±0.001^{b}	8.600±0.001^{c}	7.800±0.001^{d}
Sample K fermented with A8	9.300±0.001^{a}	8.850±0.001^{b}	8.650±0.001^{c}	7.900±0.001^{d}

*Values are the Means ± Standard Deviation where n = 3. †Values with different superscript within each row are significantly different ($p< 0.05$) using Duncan's Multiple Range Test.
Sample X: Boiled BGN flour Sample Y: Roasted BGN flour.
Sample Z: Soaked BGN flour A8: *Lactobacillus plantarum.*
B1: *Lactobacillus delbrueckii.*

Table-5. Breakdown of the trypsin in the pretreated BGN flours with single starter culture (*Lactobacillus plantarum*) and mixed starter culture (*Lactobacillus plantarum and Lactobacillus delbrueckii*).

Sample code	Breakdown of Trypsin by selected starter culture			
	Day 1	Day 3	Day 5	Day 7
Sample X fermented with A8 and B1	*0.057±0.001^{a}†	0.054±0.001^{b}	0.051±0.001^{c}	0.048±0.001^{d}
Sample X fermented with A8	0.059±0.001^{a}	0.056±0.001^{b}	0.049±0.001^{c}	0.043±0.001^{d}
Sample Y fermented with A8 and B1	0.055±0.001^{a}	0.053±0.001^{b}	0.050±0.001^{c}	0.047±0.001^{d}
Sample Y fermented with A8	0.057±0.001^{a}	0.054±0.001^{b}	0.052±0.001^{c}	0.049±0.001^{d}
Sample Z fermented with A8 and B1	0.065±0.001^{a}	0.059±0.001^{b}	0.056±0.001^{c}	0.052±0.001^{d}
Sample Z fermented with A8	0.067±0.001^{a}	0.062±0.001^{b}	0.059±0.001^{c}	0.055±0.001^{d}
Sample K fermented with A8 and B1	0.078±0.001^{a}	0.075±0.001^{b}	0.073±0.001^{c}	0.070±0.001^{d}
Sample K fermented with A8	0.080±0.001^{a}	0.078±0.001^{b}	0.074±0.001^{c}	0.072±0.001^{d}

*Values are the Means ± Standard Deviation where n = 3. †Values with different superscript within each row are significantly different ($p< 0.05$) using Duncan's Multiple Range Test.
Sample X: Boiled BGN flour Sample.
Y: Roasted BGN flour Sample.
Z: Soaked BGN flour A8: *Lactobacillus plantarum.*
B1: *Lactobacillus delbrueckii.*

Table-6. Breakdown of the protease inhibitor in the pretreated BGN flours with single starter culture (*Lactobacillus Plantarum*) and mixed starter culture (*Lactobacillus Plantarum* and *Lactobacillus Delbrueckii*).

Sample code	Breakdown of Protease inhibitor by selected starter culture			
	Day 1	Day 3	Day 5	Day 7
Sample X fermented with A8 and B1	*0.165±0.001^{a}†	0.155±0.001^{b}	0.143±0.001^{c}	0.135±0.001^{d}
Sample X fermented with A8	0.168±0.001^{a}	0.159±0.001^{b}	0.145±0.001^{c}	0.137±0.001^{d}
Sample Y fermented with A8 and B1	0.160±0.001^{a}	0.145±0.001^{b}	0.130±0.001^{c}	0.110±0.001^{d}
Sample Y fermented with A8	0.164±0.001^{a}	0.155±0.001^{b}	0.148±0.001^{c}	0.125±0.001^{d}
Sample Z fermented with A8 and B1	0.150±0.001^{a}	0.145±0.001^{b}	0.135±0.001^{c}	0.120±0.001^{d}
Sample Z fermented with A8	0.155±0.001^{a}	0.148±0.001^{b}	0.138±0.001^{c}	0.130±0.001^{d}
Sample K fermented with A8 and B1	0.350±0.001^{a}	0.347±0.001^{b}	0.335±0.001^{c}	0.325±0.001^{d}
Sample K fermented with A8	0.360±0.001^{a}	0.356±0.001^{b}	0.340±0.001^{c}	0.324±0.001^{d}

*Values are the Means ± Standard Deviation where n = 3. †Values with different superscript within each row are significantly different ($p< 0.05$) using Duncan's Multiple Range Test.
Sample X: Boiled BGN flour Sample Y: Roasted BGN flour.
Sample Z: Soaked BGN flour A8: *Lactobacillus plantarum.*
B1: *Lactobacillus delbrueckii.*

The result of the shelf-life evaluation of the samples for duration of 3 months are shown on Table 7. Bacteria and fungi count ranges from 0.33×10^{3} - 3.10×10^{3}, 0.33×10^{3} – 4.6×10^{3} respectively. Coliforms were not observed or detected throughout the period of monitoring.

This result of the sensory and organoleptic assessments of the weaning blends is shown in Figure 1. Sorghum *ogi* blend fortified with roasted BGN flours was rated best for all sensory evaluation with highest overall values (68%).

Table-7. Shelf-life monitoring of the samples.

Samples	Month 1			Month 2			Month 3		
	TBC (cfu/mL)	TCC (cfu/mL)	TFC (cfu/mL)	TBC (cfu/mL)	TCC (cfu/mL)	TFC (cfu/mL)	TBC (cfu/mL)	TCC (cfu/mL)	TFC (cfu/mL)
Sample B	0.33×10^3	0.00×10^3	0.33×10^3	1.60×10^3	0.00×10^3	3.30×10^3	3.10×10^3	0.00×10^3	4.6×10^3
Sample X	0.33×10^3	0.00×10^3	0.00×10^3	1.30×10^3	0.00×10^3	0.00×10^3	1.60×10^3	0.00×10^3	0.00×10^3
Sample Y	0.33×10^3	0.00×10^3	0.00×10^3	1.60×10^3	0.00×10^3	0.00×10^3	2.33×10^3	0.00×10^3	0.00×10^3
Sample Z	0.33×10^3	0.00×10^3	0.00×10^3	1.40×10^3	0.00×10^3	0.00×10^3	2.80×10^3	0.00×10^3	0.00×10^3

Sample B: Sorghum *ogi* flour.
Sample X: Boiled BGN flour.
Sample Y: Roasted BGN flour.
Sample Z: Soaked BGN flour.
Sample BX: Sorghum Ogi flour Fortified with Boiled BGN flour (40:60).
Sample BY: Sorghum Ogi flour Fortified with Roasted BGN flour (40:60)
Sample BZ: Sorghum Ogi flour Fortified with Soaked BGN flour (40:60).

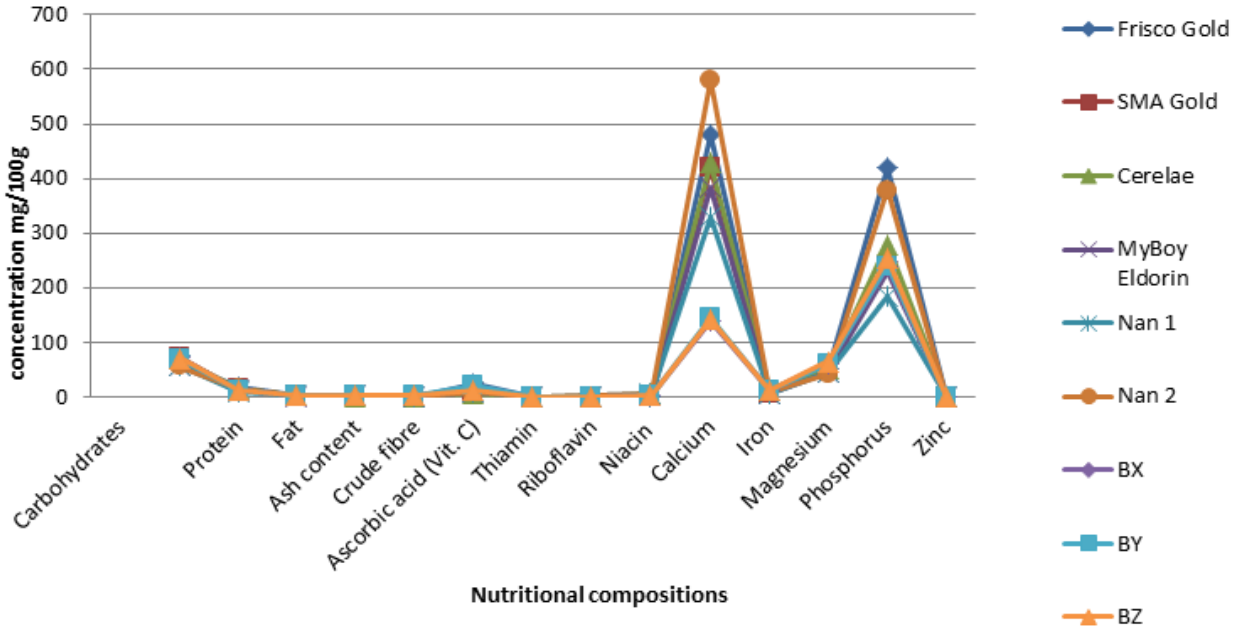

Figure-1. Comparison of different parameters between selected commercially sold weaning food and traditional fortified weaning blends.
BX: Blend of Sorghum ogi flour and Boiled BGN flour (60:40 w/w).
BY: Blend of Sorghum ogi flour and Roasted BGN flour (60:40 w/w).
BZ: Blend of Sorghum ogi flour and Soaked BGN flour (60:40 w/w).

4. DISCUSSION

Inadequate intake of protein (in quantity and quality) meals predisposes human to malnutrition, which particularly affects growing infants. *Ogi*, a product of fermentation by lactic acid bacteria from cereals (sorghum, maize or millet) commonly fed to growing infants is inadequate in protein and essential amino acids such as lysine, methionine and tryptophan (Okorie *et al.*, 2015). One strategy to ameliorate this deficiency is supplementation with legumes such as Bambara groundnut as quality protein sources in order to meet the nutritional requirements of weaning of a growing infant (Mbata *et al.*, 2009).

On the nutritional composition, there was an increased in protein content, ash content, ascorbic acid, thiamine, riboflavin, niacin and mineral content of the sorghum *ogi* when fortified with various pretreated Bambara groundnut flour. The result is consistent with other reports on the improvement in quality of cereals as observed by Onilude *et al.* (2004); Wakil and Onilude (2009) and Adeyemo and Onilude (2013). The results showed that the carbohydrate content of the sorghum *ogi* flour decreases when fortified with various pretreated Bambara groundnut flours. This agrees with the results reported by Onilude *et al.* (2004) and Wakil and Onilude (2009) that addition of legume decreases the carbohydrate content sorghum based traditional foods. The low moisture values of the weaning blends indicate that it would have a good keeping quality. This is because food spoilage organism thrives where there is adequate moisture (Edema *et al.*, 2005).

Mineral compositions (phosphorus, magnesium, iron, zinc and calcium) of the pretreated Bambara groundnut shows that the concentrations were insignificantly reduced ($P < 0.05$) in boiled BGN flour compared to roasted and soaked BGN flours. There was a reduction in calcium content in soaked BGN when compared to boiled BGN. However, roasted BGN flour, ($P < 0.05$) improved the mineral contents better than boiled and soaked BGN flours. This study agrees with earlier works by Agren and Gibson (2008). Vitamin compositions (ascorbic acid, thiamin, riboflavin, niacin and β-carotene) of the pretreated Bambara groundnut shows that the concentrations were not significantly reduced ($P > 0.05$) in soaked BGN flour when compared to roasted and boiled BGN flours. There was a reduction in thiamin content in boiled BGN and soaked BGN flour. However, roasted BGN flour, ($P > 0.05$) improved the vitamins contents better than boiled and soaked BGN flours. This study agrees with earlier works by Agren and Gibson (2008).

The results obtained from this study shows that the proximate compositions of sorghum *ogi* increases when fortified with various pretreated Bambara-nut flours. However, fortification of sorghum *ogi* with roasted Bambara groundnut flour improved the nutritional compositions of the cereals better than boiled and soaked BGN flours ($P > 0.05$). This agrees with the results reported by Adeyemo and Onilude (2013) who reported the improvement of nutritional composition of sorghum *ogi when* fortified with roasted soybean.

There was a significant reduction in tannin, phytate, protease and trypsin inhibitor content of the various pretreated Bambara groundnut when fermented with selective starter (*Lactobacillus plantarum* and *Lactobacillus delbrueckii*). As observed in this work, fermentation reduced the ANF to almost nil, a level that is safe for it to be used as supplement in weaning foods. Similar observation has been reported by Wakil and Onilude (2009) and Adeyemo and Onilude (2013) who reported the enzymatic breakdown of ANFs by *L. plantarum* in soybean.

5. CONCLUSION

The study has revealed that fortification of sorghum *ogi* flour with Bambara groundnut could alleviate problems of protein energy malnutrition (PEM). The fortified foods prepared with pretreated Bambara-nut and sorghum was nutritious and conformed to specifications as recommended by National Institute of Nutrition (NIN) and Food and Agriculture Organization (FAO) to combat malnutrition especially in low economic groups. It has special importance for use in weaning foods formulation and may provide solution to the problem of Malnutrition.

The study has provided information on the nutritional quality of locally produced weaning blends of fermented cereal (sorghum) and legume (Bambara groundnut) and isolation and selection of lactic acid bacteria with desirable technological attributes for the breakdown of antinutrient in various pretreated Bambara groundnut flours which may be used as weaning/complementary foods.

6. RECOMMENDATION

Improved starter culture development may be used to scale up the production of the product from households to medium scale level in industries. Furthermore, the introduction of appropriate starter culture techniques may constitute one of the major steps towards improving the safety, quality and security of traditional production of Bambara groundnut and sorghum fermented meal. The use of this underutilized crop should be encouraged especially in treating protein deficiency in infants.

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